TT 33: Nonequilibrium Quantum Many-Body Systems (joint session TT/DY)

Time: Thursday 15:00–18:15 Location: H22

TT 33.1 Thu 15:00 H22

Investigating the non-equilibrium dynamics of two-level systems at low temperature — •Marcel Haas, Mareike Dinger, Lukas Münch, Jan Blickberndt, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg, Germany

The dielectric loss of amorphous materials along with noise and decoherence is the major limiting factor in many applications like superconducting circuits, Josephson junctions and quantum computing. It is mainly determined by atomic tunneling systems described by quantum mechanical two-level systems (TLS), which are broadly distributed low-energy excitations in the sample. The spontaneous phonon emission of an excited TLS gives rise to a relaxation time T_1 and the interaction between TLSs with their thermally excited surrounding induces a decoherence time T_2. These effects mainly determine the measurable dielectric loss in the observed material, which we ascertain by measuring the quality factor of a bridge type superconducting LC-resonator. The dielectric medium in between the capacitor plates is a sputter deposited a-SiO_2 film. The setup shows a unique property when two off-resonant pump tones are applied symmetrically. In this limit, the resonator is emitting at the intermediate frequency of the driving fields. The underlying mechanism can therefore be explained by a nonlinear interaction of the rf-field with the TLSs and the resonator which is creating additional lines in the frequency spectrum. We present first measurements at a frequency of 1 GHz performed with a micro-fabricated superconducting resonator.

TT 33.2 Thu 15:15 H22

Photoinduced prethermal order parameter dynamics in the two-dimensional large-N Hubbard-Heisenberg model — •Alexander Osterkorn and Stefan Kehrein — University of Göttingen, Göttingen, Germany

A central topic in current research in non-equilibrium physics is the design of pathways to control and induce order in correlated electron materials with time-dependent electromagnetic fields. The theoretical description of such processes, in particular in two spatial dimensions, is very challenging and often relies on phenomenological modelling in terms of free energy landscapes. We discuss a semiclassical time evolution scheme that includes dephasing dynamics beyond mean-field and allows to simulate the light-induced manipulation of prethermal order in a two-dimensional model [1] with competing phases microscopically. We calculate the time evolution of the relevant order parameters subsequent to driving with a short laser pulse [2]. The induced prethermal order does not depend on the amount of absorbed energy alone but also explicitly on the driving frequency and amplitude. While this dependency is pronounced in the low-frequency regime, it is suppressed at high driving frequencies.

[1] Phys. Rev. B 39, 11538 (1989)
[2] arXiv:2205.06620

TT 33.3 Thu 15:30 H22

Nonequilibrium dynamics in pumped Mott insulators — •Satoshi Ejima[1], Florian Lange[2], and Holger Fehske[1,2] — [1]Institut für Physik, Universität Greifswald, Greifswald, Germany — [2]Erlangen National High Performance Computing Center, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

The study of systems under optical excitation receives tremendous attention because of both the recent rapid developments of ultrafast pump lasers and the discovery of striking phenomena not observable in equilibrium. Various numerical techniques have been applied to optically excited systems to study nonequilibrium dynamics, e.g., the time-dependent version of exact-diagonalization technique or dynamical mean-field theory. Results for nonequilibrium dynamics based on tensor-network algorithms are still rare, however.

In this talk, we propose a direct numerical scheme in the matrix-product-states (MPS) representation for the computation of nonequilibrium dynamic response functions, which can be used for general (quasi-)one-dimensional systems. Using time-evolution techniques for (infinite) MPS, we calculate, directly in the thermodynamic limit, the time-dependent photoemission spectra and dynamic structure factors of the half-filled Hubbard chain after pulse irradiation. These quantities exhibit clear signatures of the photoinduced phase transition from insulator to metal that occurs because of the formation of so-called η pairs.

[1] S. Ejima et al., Phys. Rev. Res. **2**, 032008(R) (2020)
[2] Phys. Rev. Res. **4**, L012012 (2022)
[3] arXiv:2204.09085

TT 33.4 Thu 15:45 H22

Nonequilibrium non-Markovian steady states in open quantum many-body systems: Persistent oscillations in Heisenberg quantum spin chains — •Regina Finsterhoelzl[1], Manuel Katzer[2], and Alexander Carmele[2] — [1]Department of Physics, University of Konstanz, Germany — [2]Institute of Theoretical Physics, Technical University Berlin, Germany

We investigate the effect of a non-Markovian, structured reservoir on an open Heisenberg spin chain by applying coherent time-delayed feedback control to it. The structured reservoir couples frequency-dependent to the spin chain and therefore induces a memory, thus the spin chain interacts partially with its own past. We demonstrate that with this new paradigm of a non-Markovian temporal driving scheme, it is possible to generate persistent oscillations within the many-body system and thus induce highly non-trivial states which dynamically store excitation within the chain. These oscillations occur at special points in the stability landscape and persist for different chain lengths and different initial excitations within the chain. We propose a non-invasive partial characterization of the chain by exploiting the fact that the different trapping conditions which arise each relate to specific steady states within the chain.

TT 33.5 Thu 16:00 H22

Approaching the time-dependent quantum many-body problem with Artificial Neural Networks — •Pit Neitemeier and Dante Kennes — RWTH Aachen Institut für Theorie der statistischen Physik

Numerical solutions to quantum many body problems pose a significant challenge due to the curse of dimensionality. In this work I propose a novel Artificial Neural Network (ANN) ansatz and an unsupervised learning scheme to efficiently and flexibly solve time dependent quantum many-body problems. Contrary to previous work I do not rely on ODE Solvers for the time evolution, but parametrize the full wave function using an ANN. This enables a constant cost evaluation and full differentiablity of the wave function. Furthermore I show that it is possible to learn solution bundles that continuously represent the solution for a range of external parameters. The training of these ANNs is highly parallelizeable and reduces sequential operations significantly in comparison to previous work. I benchmark the ansatz for quantum quenches, ramps and pulses of the magnetic field using 1D Ising and Heisenberg Chains.

TT 33.6 Thu 16:15 H22

Entanglement phase transitions in correlated 1D spin chains — •Monalisa Singh Roy, Jonathan Ruhman, Emanuele G. Dalla Torre, and Efrat Shimshoni — Department of Physics, Bar-Ilan University, Ramat Gan 5290000, Israel

Entanglement phase transitions have attracted immense attention in recent years especially in the context of monitored quantum circuits. In such systems the dynamics due to unitary evolution compete with the localization induced by measurements. The phase transition of quantum systems from a phase where its entanglement entropy exhibits volume law for weak monitoring, to a quantum Zeno like phase with where the entanglement entropy obeys area law is well known in many models with unitary dynamics. Some recently proposals have identified a critical phase with a logarithmic scaling of entanglement in non-Hermitian models. We explore such a critical transition in a monitored quantum spin chain model and identify the entanglement transitions in the system under both unitary and non-unitary evolutions.

TT 33.7 Thu 16:30 H22

Feynman-Vernon influence functional approach to quantum transport in interacting nanojunctions: An analytical hierarchical study — •Luca Magazzu and Milena Grifoni — University of Regensburg

We present a nonperturbative and formally-exact approach to the charge transport in interacting nanojunctions using a real-time path-integral method based on the Feynman-Vernon influence functional. Expansion of the influence functional in terms of the number of tunneling transitions results in an exact generalized master equation for the populations in the occupation-number representation, and in a formally exact expression for the current. We apply our method to the exactly solvable resonant level model (RLM) and to the single-impurity Anderson model (SIAM). For both systems, we demonstrate a hierarchical diagrammatic structure. While the hierarchy closes at the second tier for the RLM, this is not the case for the interacting SIAM. Upon inspection of the current kernel, known results from various perturbative and nonperturbative approximation schemes to quantum transport in the SIAM are recovered. Using a simplified fourth-tier scheme, analytical results for the interacting SIAM are presented both in equilibrium and nonequilibrium and with an applied magnetic field.

[1] L. Magazzù and M. Grifoni, Phys. Rev. B 105, 125417 (2022)

15 min. break

TT 33.8 Thu 17:00 H22

In-Gap Band Formation in a Periodically Driven Charge Density Wave Insulator — •Alexander Osterkorn, Constantin Meyer, and Salvatore Manmana — University of Göttingen, Göttingen, Germany

Periodically driven quantum many-body systems host unconventional behavior not realized at equilibrium. Here we investigate such a setup for strongly interacting spinless fermions on a chain, which at zero temperature and strong interactions form a charge density wave insulator. Using unbiased numerical matrix product state methods for time-dependent spectral functions, we find that driving of the correlated charge-density wave insulator leads not only to a renormalization of the excitation spectrum as predicted by an effective Floquet Hamiltonian [1], but also to a cosine-like in-gap feature [2]. This is not obtained for a charge density wave model without interactions. A mean-field treatment provides a partial explanation in terms of doublon excitations. However, the full picture needs to take into account strong correlation effects. [1] Phys. Rev. Lett. 120, 127601 (2018) [2] arXiv:2205.09557

TT 33.9 Thu 17:15 H22

Non-equilibrium phases of matter in 2D using Projected Entangled Pair States — •Augustine Kshetrimayum[1,2], Dante Kennes[3], and Jens Eisert[1,2] — [1]Freie University Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]RWTH Aachen University, Germany

We explore the highly challenging realm of non-equilibrium physics in two spatial dimensions using infinite Projected Entangled Pair States (iPEPS), a two-dimensional tensor network ansatz directly in the thermodynamic limit. By adding disorder in a translationally invariant setting through the use of auxiliary states, we find evidence of Many-body localization (MBL) and Quantum time crystals in 2D.

In our discrete disorder setting, we show that many levels of disorder is required in order to achieve localization and ultimately time crystalline behavior. We discuss how our setting can be realized in programmable quantum simulators.

TT 33.10 Thu 17:30 H22

Charge transport in hybrid semiconductor-cavity systems: an exact diagonalization study — •Sebastian Stumper and Junichi Okamoto — Institute of Physics, University of Freiburg, Freiburg, Germany

Recent experiments demonstrate that the conductivity of organic semiconductors can be enhanced by hybridization with a plasmonic surface [Nat. Mat. 14, 1123 (2015)]. Motivated by these findings, we study a two-band tight-binding chain resonantly coupled to a photonic mode by an exact diagonalization technique. First, we argue that the exciton density and photon number are suppressed by the band gap, an effect which is neglected by the commonly used rotating wave approximation. Second, we determine the excitation of the semiconductor and its impact on the conductivity beyond the rotating wave approximation, i.e., including the off-resonant terms. Clean and disordered cases are compared. Finally, we discuss the real-time dynamics of electrons and holes under a uniform electric field.

TT 33.11 Thu 17:45 H22

Interplay of disorder and interactions in a periodically driven ultracold atomic system — •Arijit Dutta — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

Periodically driven clean noninteracting systems are known to host several interesting topological phases. Particularly, for high frequency driving, they have been found to host the analogues of equilibrium topological phases, like the Haldane phase. However, upon lowering the driving frequencies these systems have been found to host anomalous phases with robust edge modes despite all Chern numbers being zero. Moreover, theoretical works have shown that adding disorder to such anomalous phases leads to quantized charge pumping through the edge modes even when all bulk states become localised. We investigate the fate of these phases in presence of electron-electron interactions of the Falicov-Kimball type.

TT 33.12 Thu 18:00 H22

Non-equilibrium optical conductivity for striped states: A time-dependent Gutzwiller analysis for the single-band Hubbard model — •Christian Martens and Götz Seibold — BTU Cottbus-Senftenberg, Institute of Physics, 03046 Cottbus, Germany

In recent years pump-probe experiments have turned out as a powerful tool to investigate the dynamics of correlated materials, e.g. transition metals or heavy fermion systems. In these experiments the system is prepared in a non-equilibrium state by a strong laser pulse, where the relaxation is afterwards examined by standard optical techniques. This method has also been applied to stripe ordered nickelates and cuprate superconductors where it allows to study the coupled order-parameter dynamics of charge- and spin-density waves and superconductivity.

Here we use the time-dependent Gutzwiller approximation for the single-band Hubbard model to analyse the non-equilibrium dynamics for stripe ground states of different symmetry. In particular we are interested in the interplay between spin and charge dynamics which is analysed by quenching the system in the charge or spin sector. This allows us to investigate the coupled relaxation dynamics as a function of the inserted energy. In contrast to the Hartree-Fock + random-phase-approximation the optical conductivity shows high-energy double occupancy fluctuations in addition to the low-energy collective mode. In the out-of equilibrium regime we find a softening of both modes depending on the inserted energy. Moreover the double occupancy exitation broadens into a continuum.